

Supplementary Material

Figure S1: Flowchart detailing sample exclusions

Figure S2: US County Map showing geographic distribution of sample counties

Figure S3: County-level factors associated with higher or lower than predicted excess mortality using WLS and Negative Binomial Models

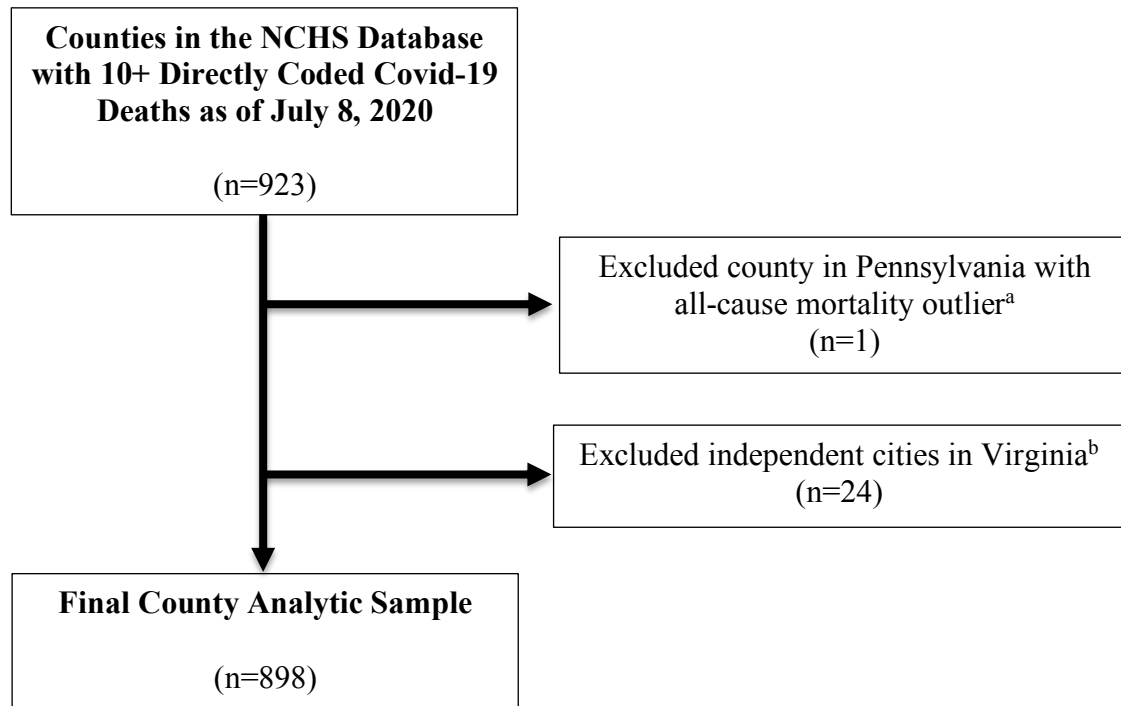
Table S1: Data sources and years for county-level factors

Table S2: Characteristics of counties included in the analysis

Table S3: Linear models of the relationship between directly assigned Covid-19 deaths, historical mortality and all-cause mortality in 2020

Table S4: Comparison of OLS, WLS, and Negative Binomial Models

Figure S1: Flowchart detailing sample exclusions



a. All-cause mortality in this county was more than 200% greater than the county with the next highest all-cause mortality.

b. We chose not to incorporate independent cities into neighboring counties because several of the neighboring counties were not included in the 923 counties represented in the dataset.

Figure S2: US County Map showing geographic distribution of sample counties (n=898)

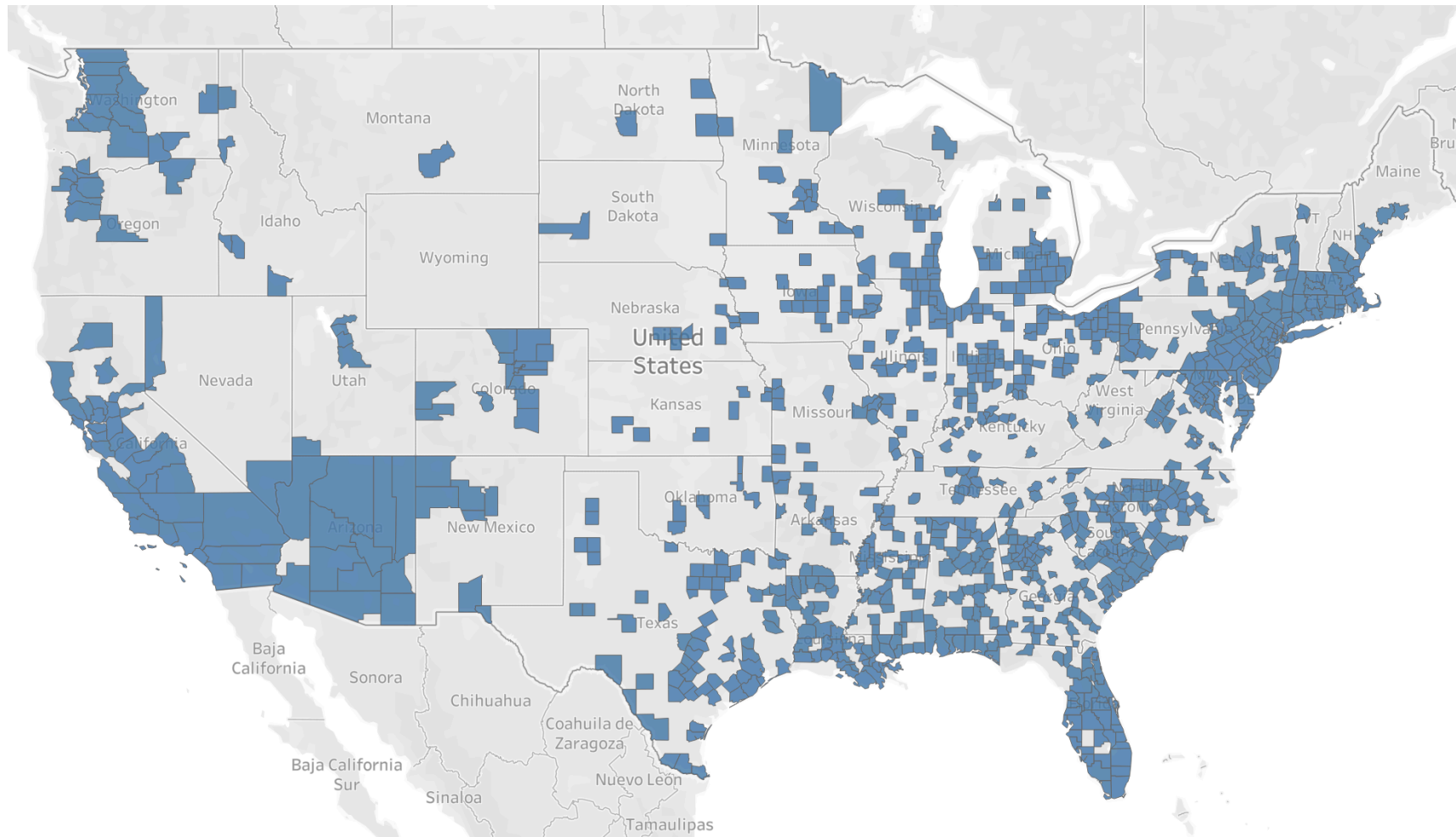
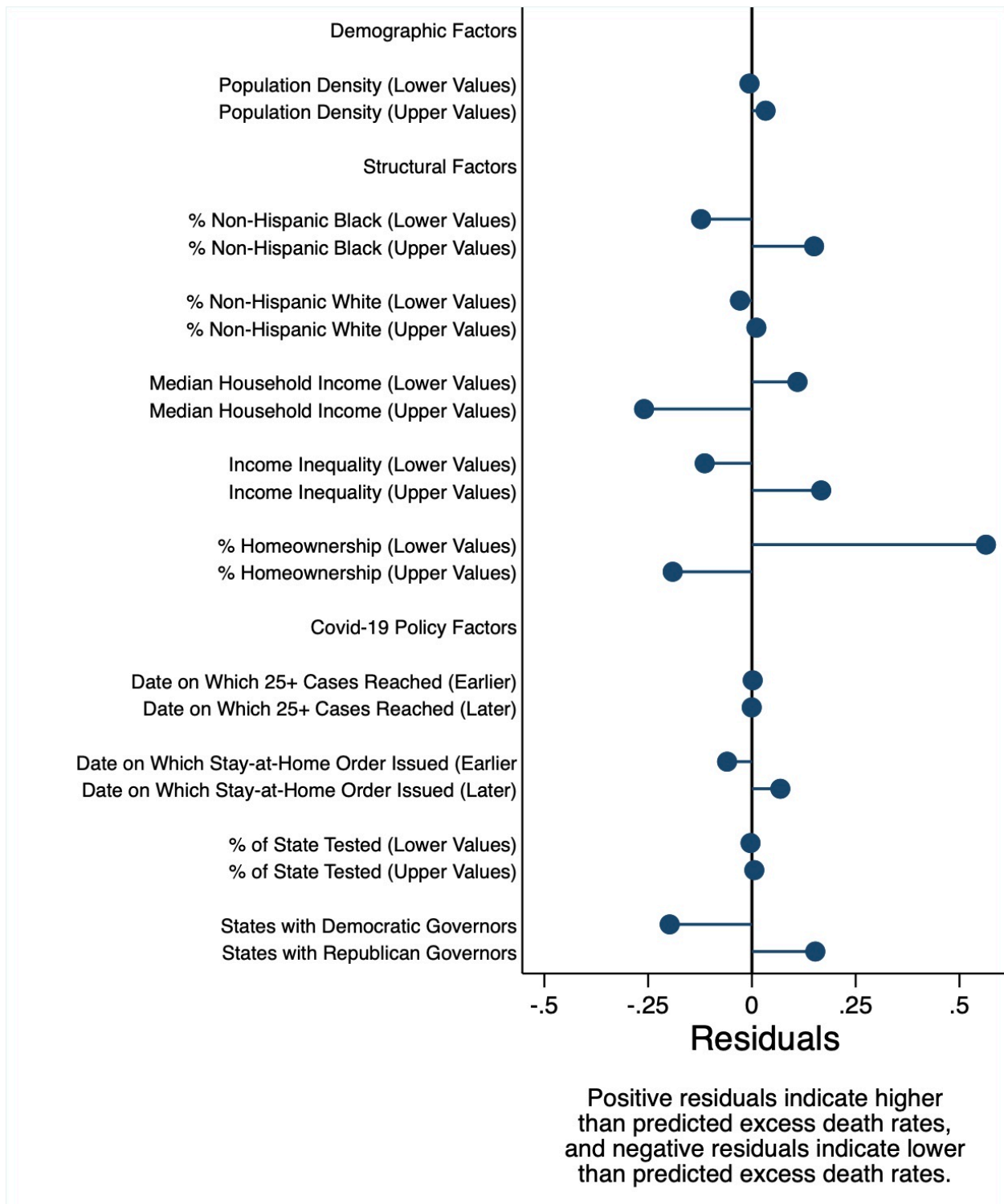
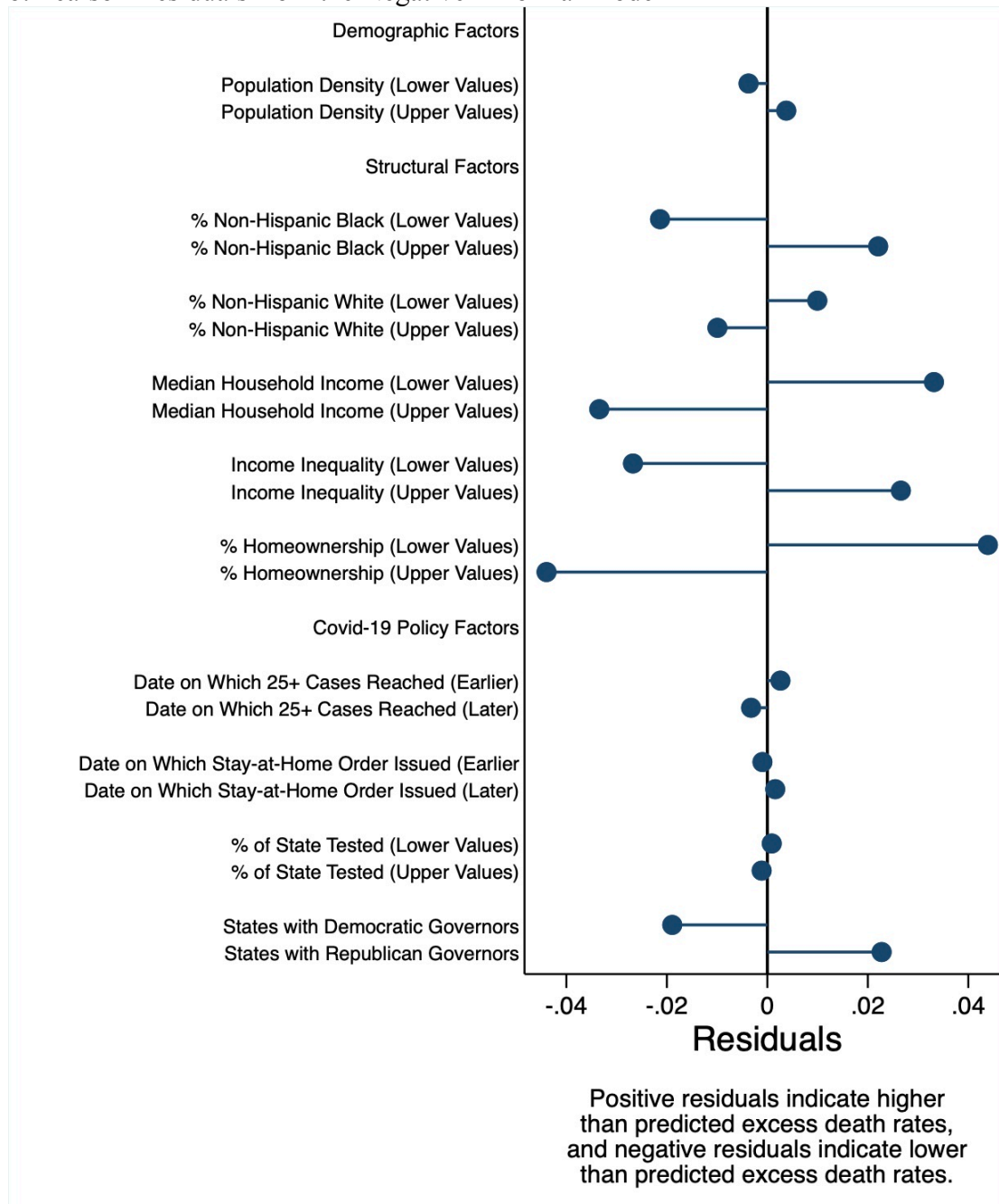


Figure S3. County-level factors associated with higher or lower than predicted excess mortality using WLS and Negative Binomial Models^{a,b,c,d}

a. Residuals from the WLS Model



b. Pearson Residuals from the Negative Binomial Model



a. $n = 898$ counties

b. Death rates reported in units of deaths per 1000 people.

c. Residuals calculated from the model: $M(i) = \alpha + \beta_1 M^*(i) + \beta_2 C(i)$, where $M(i)$ = Death rate from all causes in county i in 2020, $M^*(i)$ = Death rate from all causes, county i in 2013-2018, and $C(i)$ = Covid-19 death rate in county i in 2020. Model weighted by the 2020 population. For the Negative Binomial model, $M(i)$ = deaths from all-causes in county i in 2020 rather than the death rate, with the 2020 population used as an offset.

d. Counties stratified at the weighted median of each demographic, structural, or policy factor. Weighted means were calculated for the residuals in each dichotomous category of upper or lower values.

Table S1: Data sources and years for county-level factors

Variable	Data Source:
% 65 Years and Older	Census Population Estimates, 2018
Population Density	Census Population Estimates, 2020 and Palewire Github (https://gist.github.com/palewire/5cf017f21730ebd8303fb51e0cc7a2cd)
% Non-Hispanic Black	Census Population Estimates, 2018
% Non-Hispanic White	Census Population Estimates, 2018
Median Household Income	Small Area Income and Poverty Estimates, 2018
Income Inequality	American Community Survey, 5-year estimates, 2014-2018
% Homeownership	American Community Survey, 5-year estimates, 2014-2018
Date on Which 25+ Cases Reported	New York Times Covid-19 Cases, Historical County File (https://github.com/nytimes/covid-19-data/)
% of State Tested for Covid-19	The COVID Tracking Project, State Data (https://covidtracking.com/data/download/)
Date on Which State Stay-at-Home Order Issued	COVID-19 US state policy database (CUSP) (https://tinyurl.com/statepolicies)
State Governors' Political Parties	Kaiser Family Foundation (https://www.kff.org/other/state-indicator/state-political-parties/)

Table S2. Characteristics of counties included in the analysis (n=898)^a

Characteristic	Mean	Standard Deviation	Minimum	Maximum
<u>Demographic Factors:</u>				
Population Density ^b	2,566	7,213	6.5	71,214
<u>Structural Factors:</u>				
% Non-Hispanic Black	13.6%	12.3%	0.1%	82.0%
% Non-Hispanic White	56.4%	20.8%	2.7%	97.1%
Median Household Income	\$67,471	\$17,962	\$26,449	\$140,382
Income Inequality ^c	4.8	0.8	3.2	9.2
% Homeownership	62.2%	10.7%	19.6%	89.8%
<u>Policy Factors:</u>				
Date on Which 25+ Cases Reported ^d	03/23	10.9	03/04	07/24
Date State Stay-at-Home Order Issued ^d	03/26	5.8	03/19	04/07
% of State Tested for Covid-19 ^e	22.9%	7.4%	12.0%	45.4%
% in States with Republican Governors	45.4%	-	-	-

a. Means and standard deviations are weighted with the estimated county population in 2020.

b. Population density in units of people per square mile.

c. Ratio of household income at the 80th percentile to income at the 20th percentile

d. Mean date in 2020 reported; standard deviation reported in number of days

e. Number of Covid-19 tests per state population as of August 26, 2020.

Table S3: Linear models of the relationship between directly assigned Covid-19 deaths, historical mortality and all-cause mortality in 2020^{a,b}

	β_1	95% CI		β_2	95% CI		α	% Excess Deaths Not Attributed to Covid-19	95% CI	
All Counties (n=898)	0.99	0.94	1.03	1.26	1.15	1.36	0.318	20.4%	13.7%	27.2%
Excluding New York City (n=893)	0.98	0.93	1.03	1.28	1.14	1.41	0.325	21.8%	13.5%	30.1%
Excluding Counties in the Lower 25% of Covid-19 Deaths (n=674)	0.99	0.93	1.05	1.17	1.06	1.29	0.397	14.9%	6.4%	23.3%
All Counties, No Exclusions (n=923)	1.00	0.95	1.05	1.27	1.16	1.38	0.267	21.2%	14.2%	28.3%

a. $M(i) = \alpha + \beta_1 M^*(i) + \beta_2 C(i)$, where $M(i)$ = Death rate from all causes in county i in 2020, $M^*(i)$ = Death rate from all causes, county i in 2013-2018, and $C(i)$ = Covid-19 death rate in county i in 2020.

b. Estimated county population in 2020 used for weighting.

Table S4. Comparison of OLS, WLS, and Negative Binomial Models^a

Model	Number of Excess Deaths per 1 Directly Coded Covid-19 Death	% Excess Deaths Not Attributed to Covid-19
OLS Model ^{a,b}	1.257 [95% CI (1.150, 1.363)]	20.4% [95% CI (13.7%, 27.2%)]
WLS Model ^{a,b}	1.360 [95% CI (1.219, 1.501)]	26.5% [95% CI (18.9%, 34.1%)]
Negative Binomial Model ^c	1.257	20.5%

a. The OLS and WLS models were specified as $M(i) = \alpha + \beta_1 M^*(i) + \beta_2 C(i)$, where $M(i)$ = Death rate from all causes in county i in 2020, $M^*(i)$ = Death rate from all causes, county i in 2013-2018, and $C(i)$ = Covid-19 death rate in county i in 2020. Model weighted by the 2020 population. For the Negative Binomial model, $M(i)$ = deaths from all-causes in county i in 2020 rather than the death rate, with the 2020 population used as an offset.

b. Number of excess deaths per 1 directly coded Covid-19 death is equivalent to the regression coefficient for directly coded Covid-19 deaths.

c. We used marginal predictions to calculate all-cause mortality at ± 0.1 deaths per 1000 people from the weighted mean of directly coded Covid-19 mortality. The change in all-cause mortality was divided by 0.2 deaths per 1000 people to yield the number of excess deaths per 1 directly coded Covid-19 death.